SEX DIFFERENCES IN THE PROPORTION OF CORTEX AND MEDULLA IN THE CHICKEN SUPRARENAL

by

F.G. Sauer,

A.B. Stanford University, 1926.

Submitted to the Department of Anatomy and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

Approved by:

H.B. Latimer
Instructor in charge

H.P. Terry
Head of department.

May 19, 1931.

Table of Contents.

	Page
Introduction	1
Embryology and Phylogeny of the Suprarenal Glands	2
Relation of the Suprarenal Glands to Sex.	6
Histology of the Suprarenal Gland of the Chicken.	10
Materials and Methods.	14
Results and Conclusions.	18
Summary.	23
Bibliography.	24
Appendix, tables.	27
Photographs.	32

Introduction.

The present study was undertaken in an attempt to throw light on the relationship between the suprarenal glands and secondary sex characteristics. Investigations cited below have shown that the size of the adult mammalian suprarenal is considerably greater in the female than in the male; that the difference is due to the presence of a greater amount of cortical material in the female glands; and that a relation exists between the quantity and activity of the cortical substance and the development and maintenance of secondary sex characteristics. However, Latimer, ('24) found no apparent difference in the weight of male and female suprarenal glands in chickens. At his suggestion the writer has attempted to determine whether or not there is a difference in the proportion of cortical and medullary material in the glands such that the female may have a greater quantity of cortical substance than the male.

The writer wishes to express his thanks for the constant aid and many valuable suggestions given by Dr. H.B. latimer in the course of the work, for the assistance of Dr. H.C. Tracy in matters relating to histology of the glands, and for the valuable help of Miss Margaret Schumann in connection with microscopic technique.

Embryology and Phylogeny of the Suprarenal Glands.

The suprarenal glands of higher vertebrates are composed of two sorts of material of different origin and function. These are called cortical and medullary substance from their relative position in the mammalian gland. The latter also goes by the name of chromaffin (chromaphil, phaeochrome) substance from its apparent affinity for salts of chromium. It is generally agreed that the cortical material is derived from mesoderm and the medulla from ectoderm. The cortex appears as a growth into the coelom from the coelomic epithelium medial to the mesonephros. Into the mass so formed, ectodermal cells migrate from the neural crest along with other cells which migrate ventrally from the same origin to form the dorsal root ganglia and ganglia of the sympathetic trunk and plexuses. In mammals these penetrate to the center of the mass and clump together there.

The embryonic stages of relationship between cortex and medulla in mammals correspond strikingly to the progressive series of relationships found in the vertebrate phyla, as reviewed by Vincent ('12).

In cyclostomes the homologue of the cortical material exists as irregular clumps in the walls of

blood vessels bordering on the dorsal part of the coelom, while the chromaffin material is entirely separate from these and is found as strips of tissue along large arteries.

In elasmobranchs the interrenal bodies, of cortical substance, are paired or single rods lying between the kidneys, and the chromaffin material is found as segmentally arranged clumps on branches of the aorta, in close relation to ganglia of the sympathetic trunk. Ganoids and teliosts have cortical material in clumps in or in relation to the kidney, and chromaffin substance in the walls of the cardinal veins. In general, fishes have cortical material in clumps in relation to the kidney, and chromaffin material along the dorsal blood vessels close to the sympathetic ganglia to which they are related in origin.

The amphibian suprarenal consists of streaks of material on the ventral surface of the kidney, containing columns of cells of cortical substance. Mingled as clumps of cells with the cortical substance, or existing as separate streaks on the kidney, are found the chromaffin cells.

In birds, cortical and medullary material are closely intermingled throughout the substance of the suprarenal gland, the medullary material being found as strands or clumps benetrating between columns of cortical cells.

The relationship in reptiles is essentially similiar, but in some the medullary cells may not have penetrated so completely, and remain in greater amount on the surface.

In mammals the migration of medulla into cortex terminates with the chromaffin cells gathered together in the center of the gland, and normally entirely enclosed in cortex. The arrangement is especially significant when taken in relation to the blood supply of the gland. Arteries ramify on the surface of the gland and send capillaries through the cortex into sinuses between clumps of medullary cells. These in turn drain into a large central sinus. The arrangement is such that all blood must pass through the gland first in intimate contact with cortical cells and then through medulla.

In higher vertebrates both cortical and medullary cells may be found outside the main masses in the suprarenals. These are described in detail by Vincent ('12). Clumps of chromaffin cells (paraganglia) may be found in relation to the sympathetic ganglia of the trunks and plexuses, or similiar clumps may occur on the aorta (abdominal chromaphil body). Other masses may be found in connection with cortical substance in the retroperitoneal space, forming true accessory suprarenals.

Accessory cortical bodies without medulla may occur in the neighborhood of the suprarenals.

The embryology of the chicken suprarenal has been described by Hays ('14). The cortex appears at 96 hours of incubation as a thickening of the peritoneal epithelium ventral and medial to the mesonephros, ventral to the abdominal aorta, and dorsal to the hind gut. The cells become grouped to form oval masses on each side of the aorta. At 120 hours of incubation large oval cells begin to migrate ventrally from the sympathetic trunks. Most of these pass to the ventral side of the aorta and form ganglia of the prevertebral sympathetic plexuses. Some of the migrating cells become attached to the cortical masses and migrate into them, to become finally arranged as clumps, mostly around veinous blood spaces.

Relation of the Suprarenal Gland to Sex.

As the suprarenal gland is a compound organ the functions of its component parts must be considered separately. The medullary portion has long been known to have a high content of adrenalin, apparently formed there, which gives it the characteristic chromaffin reaction. It is generally considered established that stimulation of the sympathetic nerves to the gland results in increased secretion of adrenalin into the blood. The secreted adrenalin reinforces the action of the thoraco-lumbar sympathetic system.

Knowledge of the action of the cortical part of the suprarenal has recently been increased by the extraction from it of a substance termed "cortin", described by Hartman ('30). The extract was found to relieve the symptoms of suprarenal deficiency in adrenalectomized cats, so that the animals could be kept alive indefinitely after the removal of both suprarenals, or restored to health when near death from adrenal insufficiency. As the symptoms of adrenal deficiency are mainly an extreme muscular weakness, it is supposed that normal cortex secretes a substance into the blood which is necessary for the maintenance of the contractility of muscle tissue. A preliminary study by Pancratz ('31) points to a connection between the beginning of foetal

movements and the development of the suprarenal.

The evidence indicates that the cortical part of the suprarenal gland is indispensable for the maintenance of normal life, while the medullary portion is not so important. In lower vertebrates where cortical and medullary elements are separate, removal of the medulla does not necessarily cause death, while complete removal of cortex is fatal. Administration of cortin to adrenalectomized animals can apparently maintain them in a normal state without the administration of adrenalin to replace the secretion of the medulla.

The suprarenal gland, and more especially the cortical part, is evidently connected with secondary sex characteristics. It has long been known that in mammals the gland is larger in the female than in the male, and quantitative data on the relation is now available.

Jackson ('13) gives the following mean percents of body weight of the suprarenals of the albino rat:

	Newborn	7 days	20 days
Male	.0382 ± .00068	.0233 ± .00062	.0360 ± .00089
Female	.0412 ± .00091	.0225 ± .00056	.0430 ± .0017

	6 weeks	10 weeks	5 months
Male	.0273 ± .00074	.0185 ± .00055	.0158 ± .00036
Female	.02485 ± .00092	.0257 ± .00049	.0260 ± .0000

	1 year
Male	.0160
Female	.0278

Hatai ('13) gives formulas which indicate a

similiar heavier gland in the female:

$$\text{Male} = 0.0000855\ (\text{Bd. wt.} + 3) + 0.113 \log (\text{Bd. wt.} + 3) - 0.0093$$

$$\text{Female} = 0.00023\ \text{Bd. wt.} + 0.00388 \log \text{Bd. wt.} - .0020 \quad [\text{Bd. wt.} > 30]$$

"The constants for the formulas were determined from 145 males and 113 females respectively.... The sex difference becomes clearly marked in rate of about 30 grams in body weight. The difference becomes greater as the rats increase in weight."

J.C. Donaldson ('19) shows graphs which indicate that the suprarenal of the female albino rat is about one and one-half times as heavy as that of the male. The glands of the females were found to contain relatively less medulla than those of the male, indicating that the difference in gross weight represents a greater amount of cortex in the female.

H.H. Donaldson, ('24) says, "The volume of medulla relative to the entire gland decreases rapidly from birth to 50-100 grams of body weight, after which it increases in the male but remains constant in the female. The greater weight of the suprarenal in the female is therefore due mainly to the greater weight of the cortex."

Investigations cited by Abel and Geiling ('28) show that young rats fed with suprarenal gland grew more

rapidly and showed an earlier development of gonads than the controls. These authors state that sexual precosity, marked by development of adult generative organs in children of either sex from four to six years of age, may result from tumors of the suprarenal cortex, as well as from tumors of other endocrine organs. Cases are mentioned of slow growth of benign tumor in the cortex of the suprarenal of girls, associated with the appearance of male secondary sex characteristics, and atrophy of the uterus and breasts.

While the nature of the relation of the suprarenal cortex to sex is not completely known, it is evident that in mammals investigated for this point the male has more cortex in proportion to body weight than the female.

Histology of the Suprarenal Gland of the Chicken.

The cortical and medullary material of the suprarenal gland are distinguishable histologically by the internal structure of the cells and by their staining reactions. The characteristic "chromaffin reaction" of medulla, while it gives a ready means of detecting masses of the substance, was not found satisfactory for differentiation in microscopic sections. The reaction consists of the material assuming a brown color when treated with chromates. The reaction is shown by Kingsbury ('11) to be due to the presence of adrenalin in the medulla, the adrenalin acting as a reducing agent. The brown color is not sufficiently intense in microscopic sections to permit easy identification of areas of medulla.

With the hematoxylin-eosin stain as used in this investigation, cortex is stained red and medulla blue.

The suprarenal glands of chickens have cortical and medullary material intimately mixed together. So far as could be estimated without measurement, the proportion is about the same in all parts of the gland; peripheral and central parts show about the same percentage of cortex and medulla. The arrangement of cell masses, however, is different in central and peripheral

portions and suggests that of the mammalian gland.

In the suprarenal gland of mammals, a peripheral glomerular zone, intermediate fascicular zone, and central reticular zone are distinguished in the cortex which surrounds the central mass of medulla. In all the glands of chickens examined a glomerular zone resembling that of mammals in arrangement of cortical cells was distinguishable at the periphery. The central mass of the gland has an arrangement similiar to that of the reticular zone of mammals. In a few glands a radial arrangement of cell columns connecting the central reticular part and peripheral glomerular zone is visible. It is to be noted, however, that the arrangement in mammals described above applies to cortex with no admixture of medulla, while that of the chicken applies to a mixture of the two sorts of cells.

In the peripheral part of the glands the cortical cells are arranged in columns and folded sheets. The cortical cells in this region are elongated, with their long axis transverse to the plane of the column or sheet. Cortical cells of the central part of the gland are arranged in clumps and are of irregular shape. Medullary cells in all parts of the gland have an irregularly rounded shape.

The blood supply of the gland is through capillary sinuses whose endothelium lies directly against the cortical and medullary cells. Only in a few apparently pathological areas of some glands was any connective tissue visible between endothelium and gland cells. A few typical thick walled small arteries found in some glands appear to pass through without branching in the glands. Capillary sinuses of the peripheral part of the gland have in general a radial direction. Those of the central part are small and irregular. Mingled with the small capillary sinuses of the central part are a few much larger ones, recalling the single large central sinus of the mammalian gland.

All glands examined have a large sympathetic ganglion attached to their surface at some point. Frequently, small clumps of ganglion cells are found scattered over the surface of the gland. Nerve fibers were not visible with the hematoxylin-eosin stain used except where they formed bundles, which could be seen among the ganglion cells and in a few cases passing into the gland. In only one of the male glands were any ganglion cells found within the main mass of the gland. In the female glands, groups of ganglion cells in the gland were of frequent occurrance.

In glands 2R and 9L, small accessory masses composed of both cortex and medulla were found, attached

to, but separate from, the main mass of the gland.

Evidence of pathological changes was found in several glands. Lymphoid infiltration, as noted in Table 3, was found in considerable amounts in three glands. Very slight amounts were found in two others. In all cases the lymphoid infiltration appeared to affect medullary areas only.

Gland 2R had undergone such changes that it was not recognized as suprarenal when first examined. Its cells were very small, especially the medullary cells. Large masses of nerve fibers were attached to it, but ganglion cells were either absent or so degenerated that they were not recognized.

Gland 10L appeared nearly normal in every respect except staining capacity. Cortex and medulla were so little differentiated that they could not be drawn. The right gland of the same bird, which had the same treatment, showed clear differentiation of cortex and medulla.

Materials and Methods.

The glands studied were taken from 19 single comb white Leghorn chickens from a local poultry company. Vigorous adults were selected, ten cocks and nine hens. The glands of the cocks were taken during 1929 and those of the hens during 1930, at the same period of the year in each case so that any seasonal changes in the glands would not affect the result.

The birds were killed by bleeding from the jugular veins and the glands removed rapidly and freed from adhering fat and connective tissue as completely as possible without injuring them. They were then dropped into Zenker's fluid in individual weighing bottles and the weight of each gland determined from the increase in weight of the bottle and contents.

The procedure of fixing and imbeding was as follows:

Zenker's fluid	48 hours
Running water	12 "
Alcohol, 50%	2 "
" , 70% iodine	At least 4 days, until iodine was no longer decolorized.
" , 70%	24 hours
" , 80%	2 "
" , 95%	2 "
" , 100%	3 "
Alcohol and xylol	30 minutes
Xylol	2 hours
Melted paraffin	2 hours, changed after first 15 minutes.
Imbed in paraffin.	

The procedure was kept the same for every gland so that any difference in shrinkage of the various materials in fixation would not affect the result.

All the glands taken were sectioned and mounted. Two were pathological and not used, as noted in Tables 1, 3, and 4. The glands were designated by the serial number of the bird and L or R to indicate left or right gland.

The glands of the first two cocks were sectionedd to a thickness of 7 microns. All others were sectioned to 10 microns. For birds 1 to 5, all sections were mounted. For the remainder, every fifth section was mounted.

The slides were stained with Delafield's hematoxylin and Grubler's alcohol soluble eosin, .5% solution in 70% alcohol. Other eosins tried did not give good differentiation. The time of staining was varied somewhat as proved best for each gland.

The relative volumes of the various materials in each gland was determined by projecting areas of the stained sections on paper, drawing the outlines of the areas of the various materials, and then separating these and determining their weight.

Glands 6L, 6R, and 7L were projected with a magnification of 500 times. They were sampled by setting

the mechanical stage of the projecting microscope successively to predetermined readings which represented points distributed over the entire slide, and drawing what was found in the field at each point. The circular field drawn was 9 inches in diameter, and at least 50 fields were drawn for each gland. The remainder of the glands were projected with a magnification of 350 times, which proved more satisfactory, and the sampling was done by taking strips from center to edge of sections spaced equally throughout the gland. At least 50 fields were drawn for each gland. These were rectangular, 6 by 8 inches.

The material of the areas drawn was labled as cortex, medulla, blood spaces, and extraneous. The latter included the capsule, ganglion cells, fat, or any other adherent material. In three glands lymphoid infiltration was found in sufficient amounts to be drawn, and this was kept separate from the other areas.

The method of determining areas by weight was used by Jackson ('17) and Rasmussen ('28) in determining the areas of cells and nuclei in projected sections of hypophysis. Scammon and Scott ('27) investigated the relative merits of a number of methods of estimating areas. They mention the method of counting squares on coordinate paper. The planimetric method was found good

for large areas, but was found to give large errors when used for small irregular areas, and for these the "area by weight" method was found better. As the method assumes constant weight per unit of area, the variability of the paper was investigated. Paper of good grade was found to have a coefficient of variability of 2.50. Eastman "Kodaloid, No. 3", a sheet celluloid material, was found to have a coefficient of variability of 1.62.

Paper used for drawing the sections in this study was Scriptum Ledger, 19 by 24 inch sheets, 44 pounds to the ream, from the Missouri Interstate Paper Company. Samples one inch square were taken from each corner of each sheet, dried in a dessicator, and weighed. The coefficient of variability was found to be 1.73.

The areas corresponding to the various materials on the drawings were cut out with scissors, placed in separate envelopes, and dried in a dessicator over fused calcium chloride. It was found by test that they were brought to constant weight in 15 hours. In order to insure thorough drying, all paper was left in the dessicator for at least 48 hours.

After drying, the paper corresponding to each material was weighed separately. The weights determined are given in Table 3.

Results and Conclusions.

The results of all weighings of chickens, glands, and paper are tabulated in Tables 2 and 3 (appendix). Percentages derived from these are shown in Table 4 (appendix) and Table 1.

Although the weight of the female gland averages less than that of the male gland, it forms a slightly larger percent of the body weight, on account of the smaller body weight of the female, as indicated in Table 4.

The percent of blood and extraneous materials found is variable and not significant. Since the clotting time of chicken blood is extremely variable, (Thompson and Carr, '23) the extent of bleeding and consequently the amount of blood left in the vessels, is variable. Variations in the amount of extraneous material indicate only varying degrees of success in freeing the gland from adhering material. In several cases the gland was adherent to the surface of a large blood vessel, from which it could not be removed without injury.

The average percentage which the gland forms of the body weight of the chicken is .00510 .00012 for males and .00573 .00020 for females. To the limited degree possible with this small number of cases, the result verifies Latimer's conclusion that the weight

TABLE I

CORTEX AND MEDULLA, PERCENT OF BODY WEIGHT

Males			Females		
No.	Cortex, Percent	Medulla, Percent	No.	Cortex, Percent	Medulla, Percent
1L	.00176	.00247	11L	.00219	.00204
1R	.00232	.00276	11R	.00175	.00071
2L	.00178	.00130	12L	.00281	.00219
2R*			12R	.00308	.00263
3L	.00178	.00091	13L	.00145	.00119
3R	.00249	.00122	13R	.00183	.00088
4L	.00251	.00105	14L	.00223	.00182
4R	.00219	.00122	14R	.00290	.00230
5L	.00186	.00082	15L	.00238	.00113
5R	.00155	.00061	15R	.00189	.00086
6L	.00179	.00251	16L	.00231	.00170
6R	.00195	.00318	16R	.00256	.00111
7L	.00257	.00156	17L	.00316	.00152
7R	.00273	.00174	17R	.00392	.00143
8L	.00245	.00241	18L	.00363	.00141
8R	.00212	.00163	18R	.00490	.00147
9L	.00251	.00144	19L	.00320	.00084
9R	.00237	.00171	19R	.00359	.00091
10L*					
10R	.00129	.00144			
Av.	.00211 ±.00006	.00164 ±.00012	Av.	.00276 ±.00014	.00145 ±.00009

* Pathological, not used.

is approximately the same proportion of the body weight in the two sexes, as the difference is too small in proportion to the probable error to be sinsidered significant.

Weights of the pairs of glands were compared with weights predicted by Latimer's formula ('24). The average actual weight exceeded the average predicted weight by 1.7% for males and 9.5% for females.

In both sexes, the average weight of the left gland exceeded that of the right, but not sufficiently to be considered significant with the small number of cases used. In the male the left gland was heavier in 7 cases out of 10. In the female it was heavier in 5 cases out of 9. The average weights were:

	Left	Right
Male	.114 gm.	.103 gm.
Female	.097 "	.091 "

The percentage of cortex and medulla, shown in Table 4, is in nearly all cases closely similiar for glands from the two sides of the same bird. The proportion varies less between the left and right glands of the same bird than it does on the average between glands of different birds.

In general, where the gross weight of the gland is large its percentage of cortex is small, and vice versa. The percentage which cortex forms of the weight of the bird is less variable than either the gross weight of

the gland or the percent of cortex in the gland. This is more evident in the male glands than in the female. So far as the male glands are concerned, the weight of cortex is fairly constant, and variations in the gross weight of the gland are due mainly to a variable amount of medulla.

The procedure used permits direct calculation of the percent which the suprarenal gland forms of the body weight of the bird. It also gives percentages by volume of the various materials in the gland. In order to know the percentage by weight which each material in the gland forms of body weight of the bird, it would be necessary to know percentages by weight instead of by volume of the materials in the gland. Since this can not be determined, it is necessary to make an assumption as to the specific gravity of the component materials of the glands. The assumption was made that cortex and medulla are of the same specific gravity, and data of Table 1 was calculated accordingly. The assumption cam not introduce any serious error, as it is applied to the glands of the two sexes to be compared.

The mean percentage weights of cortex in the two sexes is given in Table 1 as:

Male	.00211 ± .00006
Female	.00276 ± .00014

This is a difference of 31 percent. The difference is approximately 11 times the probable error of the mean of the male series and 4 1/2 times the probable error of the female mean. While a larger ratio of difference to probable error is to be desired, the result would justify at least a tentative conclusion that the female domestic fowl actually has more cortex in proportion to body weight than the male. A larger number of specimens would permit a more definite conclusion.

An assumption that the difference in amount of cortex is in any way directly responsible for producing secondary sex characteristics would not be justified, as there is considerable overlapping of the two series. Birds 11 and 15, females, each have one gland with less cortex than the male average, and bird 13, female, has less cortex in each gland than the male average. In bird 13 the total amount of cortex on the two sides is considerably below the male average, and in bird 15 it is very slightly below the male average. With these exceptions the female glands, individually and by pairs, have more cortex than the male average. The male glands, both individually and by pairs, have without exception less cortex than the female average.

The greater variability of the percent of cortex in the female suggests that the amount of cortex

may vary at different periods of ovulation. The standard deviation of the percent of cortex is .00039 for males and .00086 for females. Nothing is known of the history of the birds, other than that they appeared to be in good health when they were killed.

The most important conclusion to be drawn from this study is that which pertains to the relative amount of cortex, as a percent of body weight. The result would indicate that chickens resemble mammals in having a larger percent of cortex in the female, and it explains the correspondence of the gross weight of the suprarenal in the two sexes as being due to a smaller percent of medulla, approximately offsetting the larger pefcent of cortex, in the female.

Summary.

1. The female chicken has approximately 30 percent more suprarenal cortex in proportion to body weight than the male, although the gross weight of the glands is about the same percent of body weight in the two sexes.

2. The amount of suprarenal cortex is more variable in the female than in the male, suggesting a physiological variation.

3. The suprarenal of the chicken shows a configuration of cell masses suggesting in general appearance that of mammals.

4. The weight of the suprarenal gland was not found to be significantly different on the two sides in either sex.

Bibliography.

The following are selected, from a list of some 150 titles gathered, as having contributed more or less directly to the development of this study.

Abel, J.J. and E.M.K. Geiling 1928 The Hormones of the suprarenal glands. In "Chemistry in medicine." The Chemical Foundation, Inc.

Donaldson, H.H. 1924 The rat. Wistar Press.

Donaldson, J.C. 1919 Relative volumes of the cortex and medulla in the adrenal gland of the albino rat. Am. Jour. Anat., vol. 29, pp. 291-298

Gaskell, W.H. 1916 The involuntary nervous system. Longmans, Green, and Co.

Hartman, F.A. 1930 Cortin, vital hormone of the adrenal cortex. Endocrinology, vol. 14, pp. 229-232.

Hatai, S. 1913 On the weights of the abdominal and thoracic viscera, the sex glands, and the eyeballs of the albino rat (mus norvegicus albinus) according to the body weight. Am. Jour. Anat., vol. 15, pp. 87-120.

Hays, V.J. 1914 The development of the adrenal glands of birds. Anat. Record, vol. 8, pp. 451-474.

Hill, W.C.O. 1930 Observations on the growth of the suprarenal cortex. Jour. of Anat., vol. 64, pp. 479-502.

Howard-Miller, E. 1927 A transitory zone in the adrenal cortex which shows age and sex relationships. Am. Jour. Anat., vol. 40, pp. 251-294.

Jackson, C.M. 1913 Postnatal growth and varáábility of the body and various organs in the albino rat. Am. Jour. Anat., vol. 15, pp. 1-68.

---------- 1917 Effects of inanition and refeeding upon the growth and structure of the hypophysis in the albino rat. Am. Jour. Anat,, vol. 21, pp. 321-358.

---------- 1919 The postnatal development of the suprarenal gland - and the effect of inanition upon its growth and structure in the albino rat. Am. Jour. Anat., vol. 25, pp. 221-289.

Kingsbury, B.F. 1911. The term "chromaffin system" and the nature of the "chromaffin reaction." Anat. Record, vol. 5, pp. 11-15.

Latimer, H.B. 1924 Postnatal growth of the body, systems and organs of the single comb white Leghorn chicken. Jour. Agricultural Research, vol. 29, pp. 363-397.
---------- 1925 The relative postnatal growth of the systems and organs of the chicken. Anat. Record, vol. 31, pp. 233-253.
---------- and J.A. Rosenbaum 1926 A quantitative study of the anatomy of the turkey hen. Anat. Record, vol. 34, pp. 15-23.
---------- 1927 Correlations of the weights and lengths of the body, systems, and various organs of the turkey hen. Anat. Record, vol. 35, pp. 365-377.

Lucas Keene, M.F. and E.E. Hewer 1924 Glandular activities in the human foetus. Lancet, ii, pp. 111-112.
---------- 1927 Observations on the development of the human suprarenal gland. Jour. of Anat., vol. 61, pp. 302-324.

Pannrata, D.S. 1931 The development of the suprarenal gland of the albino rat, with a consideration of its possible relation to the origin of foetal movements. Anat. Record, vol. 49, pp. 31-50.

Rasmussen, A.T. 1928 The weight of the principal components of the normal male adult human hypophysis cerebri. Am. Jour. Anat., vol. 42, pp. 1-27.

Scammon, R.E. and G.H. Scott 1927 The technique of determining irregular areas in morphological studies. Anat. Record, vol. 35, pp. 269-277.

Schäfer, E.A. 1926 The endocrine organs, an introduction to the study of internal secretion.

Thompson, T.J. and I.L. Carr 1928 The relation of certain blood constituents to a deficient diet. Biochem. Jour., vol. 17, pp. 373-375.

Vincent, Swale 1912 Internal secretion and the ductless glands. Edward Arnold.

TABLE 2, WEIGHTS OF BIRDS AND GLANDS.

Males.

No.	Date, 1929	Wt. bird grams	Left or Rt	Wt. gland grams
1	Oct. 5	2523	L	.153
			R	.170
2	Oct. 10	2185	L	.085
			R	.075
3	Oct. 10	2209	L	.076
			R	.112
4	Oct. 10	1782	L	.077
			R	.069
5	Oct. 17	1956	L	.063
			R	.074
6	Oct. 19	1657	L	.123
			R	.112
7	Nov. 9	1942	L	.113
			R	.106
8	Nov. 9	2206	L	.156
			R	.108
9	Nov. 19	2016	L	.095
			R	.123
10	Nov. 21	2311	L	.169
			R	.088

Females.

No.	Date, 1930	Wt. bird grams	Left or Rt.	Wt. gland grams
11	Oct. 7	1399	L	.077
			R	.052
12	Oct. 7	1471	L	.102
			R	.107
13	Oct. 21	1785	L	.067
			R	.061
14	Oct. 21	1889	L	.099
			R	.120
15	Oct. 28	1555	L	.096
			R	.058
16	Oct. 28	1706	L	.115
			R	.094
17	Oct. 28	1457	L	.105
			R	.100
18	Nov. 11	1778	L	.118
			R	.130
19	Nov. 11	1727	L	.094
			R	.096

TABLE 3, WEIGHT OF PAPER.

Males.

No.	Grams of paper representing:				
	Cortex	Medulla	Blood spaces.	Extraneous.	Lymphoid.
1L	60.30	85.04	22.11	40.25	
1R	67.68	80.54	11.31	37.06	
2L	83.31	60.96	8.50	29.11	
2R*					
3L	153.61	78.00	18.77	41.60	4.65
3R	129.47	63.37	13.09	42.19	29.49
4L	152.11	63.14	8.56	37.78	
4R	160.08	82.40	11.125	28.24	
5L	165.68	73.26	17.36	28.72	
5R	168.31	65.87	16.90	12.58	
6L	42.87	60.06	15.29	59.36	
6R	57.05	93.13	14.10	33.81	
7L	70.82	43.17	10.84	35.35	
7R	135.07	86.12	30.65	17.72	
8L	66.47	65.23	27.75	32.51	
8R	79.82	61.51	10.13	33.74	
9L	94.54	55.62	13.21	17.49	
9R	92.82	66.91	18.10	61.01	
10L*					
10R	62.88	55.61	9.18	57.73	

* Pathological, not used.

TABLE 3, WEIGHT OF PAPER.

Females.

No.	Grams of paper representing:				
	Cortex	Medulla	Blood spades.	Extraneous.	Lymphoid.
11L	69.40	66.00	14.29	25.17	
11R	95.27	38.54	11.41	47.89	
12L	76.01	59.44	19.50	32.41	
12R	77.68	66.12	9.79	29.62	
13L	66.71	55.56	4.82	49.38	
13R	96.66	46.45	6.19	31.04	
14L	79.57	65.15	6.95	35.68	
14R	88.37	70.21	9.62	25.19	
15L	72.15	34.22	6.83	73.74	
15R	94.11	42.87	11.06	37.83	
16L	62.50	46.39	17.66	55.88	
16R	105.97	46.35	13.18	63.41	
17L	86.48	41.52	5.11	50.40	13.68
17R	110.66	40.21	17.78	24.95	
18L	107.02	41.40	2.98	44.28	
18R	128.09	38.67	8.25	16.82	
19L	116.08	30.62	6.62	44.77	
19R	124.76	31.55	4.225	32.55	

TABLE 4, PERCENTAGES - MALES

No.	Percentage weight of gland	% cort.	% med.	% blood	% extr.	% lymph.
1L	.0069	29.1	40.8	10.6	19.5	
1R	.0067	34.4	41.0	5.7	18.9	
2L	.0039	45.8	33.5	4.7	16.0	
2R*	.0034					
3L	.0035	51.7	26.3	6.3	14.1	1.6
3R	.0053	46.7	22.8	4.7	15.2	10.6
4L	.0043	58.2	24.2	3.3	14.3	
4R	.0038	57.0	29.2	3.8	10.0	
5L	.0032	58.1	25.7	6.1	10.1	
5R	.0024	63.8	25.0	6.4	4.8	
6L	.0074	24.2	33.8	8.6	33.4	
6R	.0068	28.8	47.0	7.1	17.1	
7L	.0058	44.3	26.9	6.8	22.0	
7R	.0054	50.2	32.0	11.4	6.4	
8L	.0071	34.8	34.1	14.4	16.7	
8R	.0049	43.2	33.2	5.5	18.1	
9L	.0047	52.3	30.7	7.3	9.7	
9R	.0061	38.8	28.0	7.6	25.6	
10L*	.0073					
10R	.0038	33.9	30.0	5.0	31.1	
Av.	.00510 ±.00022	44.2	31.3	7.0	16.8	

* Pathological, not used.

TABLE 4, PERCENTAGES ♀ FEMALES

No.	Percentage weight of gland	% cort.	% med.	% blood.	% extr.	% lymph.
11L	.0055	39.8	37.7	8.2	14.3	
11R	.0035	49.4	20.0	5.9	24.7	
12L	.0069	40.6	31.6	10.4	17.4	
12R	.0073	42.4	36.1	5.3	16.2	
13L	.0038	37.7	31.6	2.8	27.9	
13R	.0034	53.6	25.7	3.4	17.3	
14L	.0052	42.5	34.8	3.5	19.2	
14R	.0063	45.7	36.3	5.0	13.0	
15L	.0062	38.6	18.3	3.5	39.6	
15R	.0037	50.6	23.1	5.9	20.4	
16L	.0067	34.3	25.2	9.7	30.8	
16R	.0051	46.4	20.2	5.7	27.7	
17L	.0072	43.8	21.1	2.6	25.5	7.0
17R	.0069	57.2	20.8	9.2	12.8	
18L	.0064	54.7	21.2	1.5	22.6	
18R	.0073	66.8	20.1	4.3	8.8	
19L	.0054	58.7	15.5	3.2	22.6	
19R	.0056	64.5	16.3	2.2	16.9	
Av.	.00573 ±.00020	48.2	25.3	5.1	20.9	

Figure 1. The periphery of the suprarenal gland of a chicken, X 75. Showing glomerular arrangement of cortical cells, the medullary cells surrounding and passing between them to deeper parts of the gland. The power part of the photograph shows the reticular arrangement of the central parts of the gland.

Figure 2. Central part of the suprarenal gland of a chicken, X 75. Showing the irregular arrangement of cell masses; the smaller capillary sinuses between cell masses; and the larger sinuses into which these drain. The small artery passes through the gland without branching.

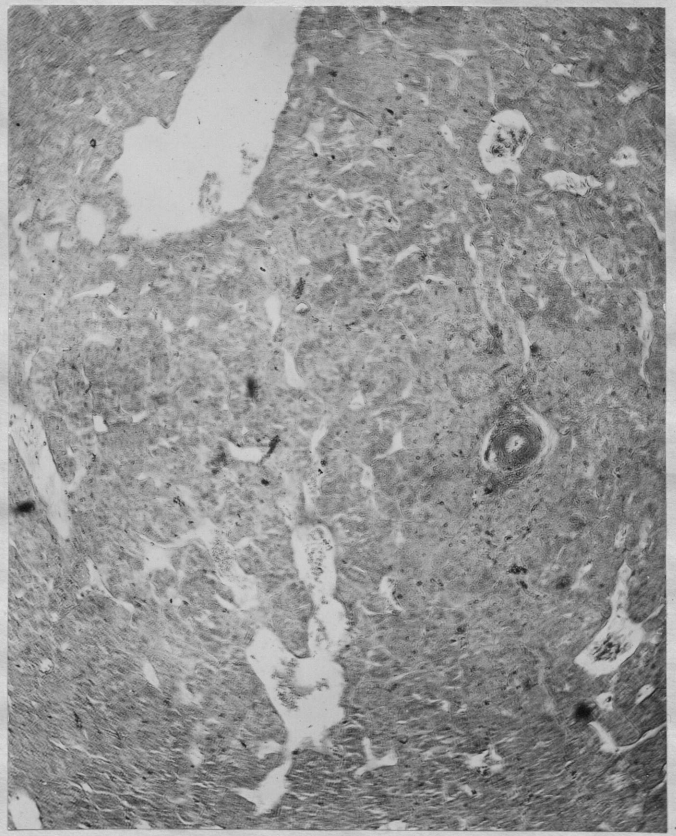

Figure 3. Sympathetic ganglion on the surface of the suprarenal gland of a chicken, X 75. Showing ganglion cells, nerve fibers, and connective tissue layer separating the ganglion from the gland.

Figure 4. Chicken suprarenal gland, X 300. Showing a clump of rounded medullary cells; capillary sinuses with endothelial lining; and cortical cells. The cortical cells are cut parallel to their length at the right and transversely at the lower left. Their long axis is transverse to the plane of the sheet of cells.